

## Original article

# Measuring Rotational Power: The Relationship between the Rotational Medicine Ball Throw, Lead Arm Velocity, and Rotational Isometric Strength Tests

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## Abstract

Rotational power is an essential quality in many athletes, such as softball players. The rotational medicine ball throw (RMBT) is a commonly used field test due to its practicality and accessibility. The lead arm velocity (LAV) test is a novel assessment created to isolate the lead arm's contribution to the rotational movement pattern of hitting. The rotational isometric strength (RIS) test has been conducted in the laboratory with a dynamometer to assess rotational strength and power via force production metrics. This study investigated the relationships between the RMBT, LAV and RIS tests in softball players through a retrospective analysis of data from 20 female athletes from one Division I college team. Testing was completed in one session: RMBT was measured on both sides, LAV on the hitting side only, and RIS variables included peak force, peak RFD, and peak impulse. Pearson's correlations calculated relationships between the RMBT, LAV, and RIS variables ( $p < .05$ ). Large significant correlations were observed between LAV and RIS left and right peak force and impulse, and peak RFD right ( $r = .484-.864$ ). LAV also correlated with the RMBT right side ( $r = .589$ ). RMBT did not significantly relate with any RIS variable ( $r = -.050-.351$ ). The RIS and LAV appeared to assess similar aspects of rotational power, and the LAV test could be used a practical performance test. These findings highlight that the LAV test related to numerous metrics from the RIS within a sport-specific movement for softball and baseball and could be useful for practitioners to evaluate rotational power in their athletes.

**Keywords:** baseball, collegiate sport, impulse, rate of force development, softball

## Introduction

Rotational power is a critical physical attribute that enhances performance in many sports, including golf, tennis, martial arts, baseball, and softball. Movements such as swinging, throwing, and punching rely on an athlete's ability to generate and transfer force through the body in a rotational pattern, making the assessment of rotational qualities essential across different sport disciplines. In softball, performance depends on foundational skills like hitting and throwing (Bordelon et al., 2024). These skills are especially reliant on full-body strength and efficient energy through the kinetic chain (Bordelon et al., 2024; Moiroux-Sahraoui et al., 2024), and require technical proficiency, motor learning, and repeated practice to optimize movement sequencing and coordination (Engelhorn, 1997; Flyger et al., 2006). Given the importance of rotational power, strength and conditioning practitioners should attempt to measure this quality in their athletes.

Rotational power can be assessed through the rotational medicine ball throw (RMBT) which measures power in the transverse plane via either throw distance or velocity. Hardy et al. (2025) examined the validity and reliability of the RMBT by comparing the maximum throw distance and velocity. Each trial was recorded using a three-dimensional motion capture system, a radar gun positioned in front of the athletes to measure throw velocity, while a tape measure was used to determine throw distance. The researchers found that velocity recorded from the radar gun demonstrated excellent accuracy ( $ICC=.97$ ), whereas throw distance demonstrated poor accuracy ( $ICC=.38$ ), when compared to the motion capture data. RMBT velocity also displayed high reliability for both the dominant and non-dominant sides across multiple sessions ( $ICC=.94$ ) (Hardy et al., 2025). These findings suggest that the RMBT velocity test provided an indication of rotational power, which would have application for athletes involved in rotational sports, such as softball players.

To isolate the lead arm's contribution in a hitting motion, the lead arm velocity (LAV) test offers a practical, accessible alternative to laboratory-based kinematic analysis by measuring arm velocity from a hitting stance using a radar gun (Szymanski et al., 2007a). Isolating the lead arm is important due to its contribution to rotational power in a swing. This concept is supported by Inkster et al. (2011), who investigated the biomechanics of a baseball swing in hitters of differing ability levels. Inkster et al. (2011) documented a significant relationship between peak left elbow (lead arm) angular velocity and bat linear velocity at contact ( $r=.499$ ;  $p<.05$ ), highlighting the lead arms importance in producing power in the swing. Effective swing performance depends on sequential force transfer through the kinetic chain—from the lower body, through the trunk, and ultimately into the shoulder, arms, hands, and bat (Bordelon et al., 2024). As the hand is the final segment in the kinetic sequence, the LAV test may effectively capture this terminal expression of rotational velocity. What could provide support for the LAV test is examining whether it relates to other measures of rotational power.

Rotational isometric strength (RIS) has been measured using laboratory equipment. Spaniol et al. (2010) investigated the relationship between rotational strength, bat speed and batted-ball velocity in collegiate baseball players. Rotational strength was assessed using a one-repetition maximum (1RM) performed on a seated torso resistance training machine, and the results indicated significant moderate correlations with both bat speed ( $r=.41$ ;  $p<.05$ ) and batted-ball velocity ( $r=.43$ ;  $p<.05$ ). Ab Razak et al. (2022) examined collegiate softball players using a 3RM protocol on the same equipment and found a moderate positive correlation between rotational strength and throwing velocity ( $r=.534$ ;  $p<.05$ ). Together, the findings from Spaniol et al. (2010) and Ab Razak et al. (2022) highlight the potential value of RIS testing in evaluating rotational performance in athletes. Although both studies used a torso resistance training machine, more recent research has employed electromechanical dynamometers. For instance, Rodriguez-Perea et al. (2024) measured rotational strength during a wood-chop exercise using a pulley system attached to a dynamometer in a sample of physically active college students. Rodriguez-Perea et al. (2024) found strong, significant correlations between RMBT velocity and distance and rotational strength ( $r=0.73-0.79$ ;  $p<.01$ ). These findings support the use of dynamometers as a method for assessing rotational isometric strength. Nonetheless,

further research is needed to document relationships between RIS variables with other tests of rotational performance.

Therefore, this research provided an introductory investigation of the relationships between three tests which measure rotational power in a sample of collegiate softball athletes. Archival data for the RMBT, LAV, and RIS were analyzed, as these assessments each measure distinct components of rotational ability. The RMBT and the LAV test provide velocity metrics. The RIS measures multiple force-time metrics—including force, rate of force development (RFD), and impulse. Documenting relationships between these tests will help show whether a change in a quality such as rotational strength could impact rotational power, while also showing whether there is redundancy in adopted multiple rotational tests in softball athletes. It was hypothesized that measures of RIS, including peak force, peak RFD, and peak impulse, would demonstrate significant relationships with LAV and RMBT velocity.

## **Methods**

### **Design**

This study involved a retrospective; cross-sectional analysis of data collected from collegiate softball players from a Division I school. Pearson's correlations were used to calculate relationships between the rotational tests: RMBT, RIS, LAV. The dependent variables were RMBT peak velocity for left and right sides, LAV peak velocity for hitting side, and RIS peak force, RFD, and impulse for both left and right sides.

### **Participants**

Data from 20 softball players from a Division I collegiate program were analyzed in this study. The data arose as a condition of monitoring conducted by the team's coaching staff (Lockie et al., 2020a). Although data was not collected for the purpose of research, the standard procedures adhered to by the strength and conditioning staff ensured that the data that was collected as accurately as possible (Lockie et al., 2020a). All players were required to be actively competing and training with the team and each player completed the university-mandated physical examination and university consent and medical forms for participation in collegiate athletics. Only players with full data sets were considered for this study. The institutional ethics committee approved the studies' use of pre-existing data (HSR-18-19-121). The study still conformed to the recommendations of the Declaration of Helsinki (World Medical Association, 1997).

### **Measurements and Procedures**

Prior to study participation, participants were instructed not to exercise heavily in the 24 hours before Testing was conducted during the off-season in a one-hour session. All athletes were familiar with the tests in this study, as they were performed as part of standard physical monitoring practices by the strength and conditioning staff (Lockie et al., 2020a). The session began with anthropometric measurements (height and body mass), followed by the team's typical dynamic warm-up protocol, which began with a floor-based mobility series targeting the thoracic spine, hamstrings and hips. Next, an activation phase was performed using mini bands to engage both upper body and lower body. The warm-up concluded with a dynamic component designed to elevate heart rate, incorporating movements such as shuffles, carioca, and A-skips. To ensure adequate recovery and minimize fatigue effects, approximately five minutes of rest was provided between each test. To maintain efficiency within National Collegiate Athletic Association (NCAA) Countable Athletically Related Activities (CARA) time restrictions (National Collegiate Athletic Association, 2024), the 20 athletes were divided into small groups of approximately four athletes. Each group was assigned to one of five testing stations and rotated through the battery in circuit fashion. This setup allowed one athlete to perform while others could rest, ensuring consistent recovery periods between maximal efforts. This testing process was routine for the collegiate athletes in this program. Moreover, circuit-style testing has occurred in other studies involving retrospective analysis of data (Bloodgood et al., 2020; Lockie et al., 2019; Lockie et al., 2020b; Lockie et al., 2020c). The RMBT, RIS, and LAV and tests were performed according to the procedures detailed in subsequent sections.

### Rotational Medicine Ball Throw (RMBT)

Each athlete performed the RMBT using a 1.8 kg (4 lb) medicine ball on their dominant and non-dominant hitting side (Hardy et al., 2025; Rodriguez-Perea et al., 2024). As softball athletes may throw and hit with different sides, both sides were tested to ensure a complete representation of rotational performance. Prior to testing, athletes completed a test-specific warm-up consisting of three self-regulated sub-maximal throws at approximately 50-75% of perceived effort. For the testing trials, each athlete performed three maximal side throws with approximately 10 seconds of rest between attempts (Taniyama et al., 2021). Throws were executed from a standardized staggered stance with the feet positioned shoulder-width apart to ensure consistency across athletes (Figure 1). Each athlete executed all throws on one side before switching to the opposite side, with no predetermined order regarding which side was performed first. Ball velocity was recorded using a radar gun (Stalker Sport 2, Stalker/Applied Concepts, Texas, USA) positioned directly in line with the path of the throw approximately 1 meter behind the ball (Hardy et al., 2025; Rodriguez-Perea et al., 2024). Velocity was recorded in miles per hour before being converted into meters per second (m/s). The highest recorded velocity from the three trials was used for analysis.



**Figure 1.** The rotational medicine ball throw test, including the (A) loading phase, (B) stride phase, and (C) release.

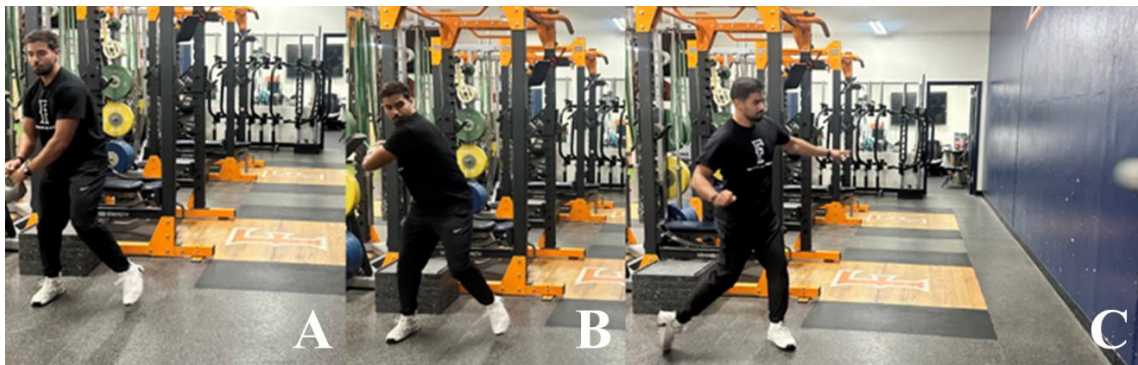
### Rotational Isometric Strength (RIS) Test

The RIS test was performed using a handheld dynamometer (VALD Performance, West Warwick, RI, USA) to assess peak force (Newtons; N), rate of force development (RFD; measured in Newtons per second [N/s]) and impulse (Newton seconds; Ns). The dynamometer was securely attached to a non-movable squat rack at chest height to ensure stability and consistent positioning throughout testing. Athletes stood in a batting-like stance with a wide base and arms straight out at chest height, gripping the handles attached to the device (Figure 2). After two self-regulated submaximal practice pulls at approximately 50% and 75% perceived maximum effort, athletes performed one maximal effort per side. They were instructed to rotate and pull as hard and as fast as possible using their entire body, simulating the rotational movement of a swing or throw. Verbal cues were given to signal the start and stop of the action. Both the left and right sides were tested.



**Figure 2.** The rotational isometric strength test.**Lead Arm Velocity (LAV) Test**

The lead arm velocity (LAV) test was performed using a 0.9-kg (2-lb) plastic kettlebell, allowing for the athletes to safely throw it against a wall. This was an innovative procedure created by the strength and conditioning staff which was used to assess training adaptations targeting swing mechanics. The athletes were told to get in their typical batting stance and hold the kettlebell with the front arm and load (Figure 3), before throwing the kettlebell into the wall using a hitting motion. The LAV test was performed only on the hitting side, as the goal was to replicate the sport-specific action of the lead arm during a swing (Hardy et al., 2025). From their hitting stance, which was identical to the RMBT position, athletes executed three self-regulated submaximal warm-up throws at approximately 50-75% of perceived effort. For testing, athletes were instructed to load and explosively throw the kettlebell forward into the wall using only their lead arm. Throwing velocity was measured with a radar gun in miles per hour and before being converted into meters per second (m/s). The radar gun was placed directly in line with the throw trajectory, approximately 1 meter behind the release point of the kettlebell, using the RMBT procedure (Hardy et al., 2025; Rodriguez-Perea et al., 2024). Each athlete completed three maximal effort attempts, and the highest velocity recorded was used for analysis.

**Figure 3.** The lead arm velocity test, including the (A) loading phase, (B) stride phase, and (C) release.**Statistical Analyses**

Statistical analyses were performed with the Statistics Package for Social Sciences (SPSS) Version 31.0 (IBM Corporation, New York, USA). data (mean  $\pm$  SD) were calculated for each variable. The initial data evaluation, conducted prior to the correlation analyses, was adapted from previous research (Lockie et al., 2024b). Normality of the data was evaluated by the Shapiro-Wilk test and skewness and kurtosis scores. Skewness and kurtosis scores between  $0 \pm 2$  were considered acceptable (George & Mallery, 2018). If data was not normally distributed and outside the accepted skewness and/or kurtosis range, stem-and-leaf plots were visually assessed to determine the presence of any extreme outliers (data points 3 times the interquartile range relative to the median) (Ghasemi & Zahediasl, 2012), and whether treatment via the winsorization was needed (Callaghan et al., 2015; Lien & Balakrishnan, 2005; Lockie et al., 2024b). However, as will be detailed, no data required treatment. Thus, Pearson's correlations computed relationships between the rotational test variables (RMBT, LAV and RIS). Significance was set as  $p < .05$ . A perfect linear positive correlation was equal to 1. A strong correlation was defined as 0.7-0.9 and -0.7 to -0.9, a moderate correlation as 0.4-0.6 and -0.4 to -0.6, and a weak correlation 0-0.3 and 0 to -0.3 (Akoglu, 2018).

**Results**

Initial review of the data indicated that most variables were normally distributed ( $p = .059-.867$ ), except for left peak RFD ( $p = .029$ ), right peak RFD ( $p < .001$ ), and right peak impulse ( $p = .017$ ). Left peak RFD had acceptable skewness (1.534) but not kurtosis (3.579), which was also the case for right peak impulse (skewness=1.606, kurtosis=4.993). Right peak RFD had both skewness (2.825) and kurtosis (9.775) values outside the study

parameters. However, none of these three variables had outliers that were considered extreme. Accordingly, they were not treated.

Descriptive data is shown in Table 1; correlation data is displayed in Table 2. LAV showed strong, significant correlations with left and right RIS impulse, and moderate, significant correlations with RMBT right, left and right RIS force, and RIS right peak RFD. The RMBT for the right or left did not significantly correlate with any RIS variable.

**Table 1.** Descriptive data (mean  $\pm$  SD) for age, height, body mass, right and left rotational medicine ball throw (RMBT), right and left rotational isometric strength (RIS; peak force, rate of force development [RFD], and impulse), and lead arm velocity (LAV).

| Variable               | Mean $\pm$ SD        |
|------------------------|----------------------|
| Age (years)            | 19.86 $\pm$ 1.42     |
| Height (cm)            | 168.35 $\pm$ 5.67    |
| Body Mass (kg)         | 70.69 $\pm$ 11.52    |
| RMBT Right (m/s)       | 9.74 $\pm$ 0.61      |
| RMBT Left (m/s)        | 9.96 $\pm$ 0.47      |
| RIS Right Force (N)    | 187.50 $\pm$ 37.84   |
| RIS Left Force (N)     | 197.90 $\pm$ 38.54   |
| RIS Right RFD (N/s)    | 1048.75 $\pm$ 446.64 |
| RIS Left RFD (N/s)     | 1155.75 $\pm$ 404.67 |
| RIS Right Impulse (Ns) | 541.35 $\pm$ 132.17  |
| RIS Left Impulse (Ns)  | 564.50 $\pm$ 121.10  |
| LAV (m/s)              | 12.13 $\pm$ 1.17     |

**Table 2.** Correlations between right and left rotational medicine ball throw (RMBT), right and left rotational isometric strength (RIS; peak force, rate of force development [RFD], and impulse), and lead arm velocity (LAV).

|                   | RMBT Right | RMBT Left | LAV     |
|-------------------|------------|-----------|---------|
| RIS Left Force    | .273       | -.117     | .489*   |
| RIS Right Force   | .351       | -.050     | .695**  |
| RIS Right RFD     | .154       | -.135     | .488*   |
| RIS Left RFD      | -.121      | -.126     | -.060   |
| RIS Right Impulse | .241       | .047      | .864**  |
| RIS Left Impulse  | .325       | -.111     | -.762** |
| LAV               | .589**     | .054      |         |

\*Significant ( $p < .05$ ) \*\*Significant ( $p < .01$ )

## Discussion

This research investigated the relationships between the RMBT, RIS and LAV tests as a measure of rotational power in softball players. A unique aspect of this study was the inclusion of the LAV and RIS, in addition to the RMBT, which is frequently used in the literature (Hardy et al., 2025; Rodriguez-Perea et al., 2024; Szymanski et al., 2007a; Szymanski et al., 2007b; Szymanski et al., 2010; Taniyama et al., 2021). It was hypothesized that the RMBT and LAV would correlate with the RIS metrics. The hypotheses were partially supported. The LAV test demonstrated significant correlations with majority of the RIS variables, as well as a strong correlation with RMBT, suggesting that LAV may measure similar underlying characteristics of rotational power. The RMBT left did not significantly correlate with any variables, and the RMBT right only showed a significant relationship with LAV. This finding suggests that RMBT velocity may not relate to the specific strength and power qualities

measured by the RIS test. These results have application for softball athletes, in addition to other athletes from sports requiring maximal rotation movements.

The RIS test can assess the rotational capabilities of an athlete by measuring peak force, RFD, and impulse. These kinetic measures are qualities that are critical for explosive actions within sport (Lockie et al., 2013; Lum et al., 2020; Maffiuletti et al., 2016; Spiteri et al., 2015). As previously stated, RIS tests have also been found to relate to sport-specific rotational movements (Ab Razak et al., 2022; Spaniol et al., 2010). For practitioners, such data can be extremely useful for assessing an athlete's ability to generate maximal force or develop it quickly, as well as when monitoring pre- and post-training changes (McGuigan, 2015). However, a limitation of the RIS test lies in its reliance on expensive equipment, with costs above \$2000 with a need for on-going subscriptions (VALD Performance, 2025). The upfront and ongoing costs of equipment such as that required for the RIS may make this test inaccessible to many high schools and colleges. It should be noted that if peak force is the primary variable of interest, a device such as a crane scale could be a viable, affordable alternative (Lockie et al., 2024a). Regardless, coaches and athletes in these environments would benefit from a field-based testing alternative of rotational power that can also reflect similar aspects of performance measured by the RIS.

The LAV test offers such an option as it is performed using a radar gun-based procedure. Radar guns can cost under \$1000 without the need for ongoing subscriptions (Stalker Sport, 2025). In this study, the LAV test demonstrated strong relationships with the RMBT right—a test previously shown to be highly reliable for assessing rotational power (Hardy et al., 2025)—providing some indication for its validity. Importantly, no previous studies have utilized the LAV test in this accessible, field-based format; prior research has typically analyzed this movement using laboratory video analysis (Bordelon et al., 2024). This makes the current findings potentially impactful, as the LAV test offers a simple, coach- and athlete-friendly method for assessing swing-related rotational performance in softball players. Future research should further investigate the reliability and validity of the LAV test, and whether the LAV test relates to sport-specific variables, such as hitting or batted ball velocity. Nonetheless, coaches may choose to use the LAV test either alongside or as an alternative to the RMBT and RIS tests when evaluating the rotational capabilities of their athletes.

The RMBT is a common field assessment for evaluating rotational power (Hardy et al., 2025; Rodriguez-Perea et al., 2024; Szymanski et al., 2007a; Szymanski et al., 2007b; Szymanski et al., 2010; Taniyama et al., 2021), valued for its low cost and accessibility, requiring only a medicine ball and radar gun or tape measure. The RMBT on the right side demonstrated a significant correlation only with LAV, indicating that measuring velocity generated by the lead arm alone may be just as effective in assessing rotational output. Interestingly, the RMBT did not show significant correlations with the RIS variables, whereas the LAV did, which was an unexpected finding. This outcome may serve as preliminary evidence supporting the expansion or modification of the RMBT into a more swing-specific assessment by isolating the lead arm component. Overall, the RMBT remains a potentially valuable tool for evaluating rotational power in athletes (Hardy et al., 2025; Rodriguez-Perea et al., 2024; Szymanski et al., 2007a; Szymanski et al., 2007b; Szymanski et al., 2010; Taniyama et al., 2021). For softball players, however, the RMBT may be complimented—or in some cases replaced—by the LAV test for its swing specificity or paired with RIS test to gain additional insight into the force-production characteristics.

There were several limitations in this study. The LAV test is a novel test used by the strength and conditioning staff at this Division I school, so more research is needed before this test can be confidently used for all softball and rotation sport athletes. More research is needed to investigate the reliability and validity of the LAV test. Moreover, the LAV was performed only on each athlete's hitting side, which may not represent the overall rotational power of athletes who throw from the opposite side. Therefore, the test may not fully capture

rotational power relevant to throwing mechanics. This study only investigated the interrelationships between three rotational tests, even though they have specificity to sports such as softball. Nevertheless, further research should also explore the relationships between these rotational power tests and variables such as batted-ball velocity to determine how well each predicts sport-specific performance outcomes. Indeed, batted-ball velocity represents a direct expression of rotational power within the context of hitting, making it a meaningful benchmark for evaluating the practical relevance of these tests (Lockie et al., 2024b; Patron et al., 2024; Spaniol et al., 2010; Taniyama et al., 2021). The sample featured archival data from 20 softball athletes from one Division I school. These athletes may not be representative of all collegiate or high-level softball players.

## Conclusion

The RIS test was strongly correlated with the LAV but not the RMBT, suggesting that the RIS and LAV may provide a metric for similar aspects of rotational performance. This finding is useful for practitioners who may not have access to specialized equipment such as dynamometers, as LAV provides a comparable, practical measure of rotational strength and power. If a coach or practitioner seeks more detailed information, such as the magnitude and rate of force production, the RIS test remains valuable due to its ability to quantify these specific metrics. However, when accessibility and simplicity are priorities, the LAV test appears to represent a practical alternative.

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